

# ASSIMILATION OF SMOS OBSERVATIONS TO GENERATE A PROTOTYPE SMAP LEVEL 4 SURFACE AND ROOT-ZONE SOIL MOISTURE PRODUCT

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## 1. INTRODUCTION

The Soil Moisture Active and Passive (SMAP; [1]) mission is being implemented by NASA for launch in October 2014. The primary science objectives of SMAP are to enhance understanding of land surface controls on the water, energy and carbon cycles, and to determine their linkages. Moreover, the high-resolution soil moisture mapping provided by SMAP has practical applications in weather and seasonal climate prediction, agriculture, human health, drought and flood decision support. The Soil Moisture and Ocean Salinity (SMOS; [2]) mission was launched by ESA in November 2009 and has since been observing L-band (1.4 GHz) upwelling passive microwaves. In this paper we describe our use of SMOS brightness temperature observations to generate a prototype of the planned SMAP Level 4 Surface and Root-zone Soil Moisture (L4\_SM) product [5].

## 2. SMOS AND SMAP INSTRUMENTS

The SMOS interferometric radiometer observes L-band passive microwave emission at a range of incidence angles and a resolution of about 40 km [2]. The SMAP mission makes simultaneous active (radar) and passive (radiometer) measurements in the 1.26-1.43 GHz range (L-band) using conical scanning at a constant incidence angle (40°) [1]. The radar resolution varies from 1-3 km over the outer 70% of the swath to about 30 km near the center of the swath. The radiometer resolution is 40 km across the entire swath. The radiometer measurements will allow high-accuracy but coarse resolution (40 km) measurements. The radar measurements will add significantly higher resolution information. The radar is, however, very sensitive to surface roughness and to vegetation structure and is thus less accurate for soil moisture estimates. The combination of the two measurements allows optimal blending of the advantages of each instrument.

### 3. SMAP L4\_SM PRODUCT

SMAP and SMOS directly observe only surface soil moisture (in the top 5 cm of the soil column). Several of the key applications targeted by SMAP, however, require knowledge of root zone soil moisture (~top 1 m of the soil column), which is not directly measured by SMAP. The foremost objective of the SMAP L4\_SM product [5] is to fill this gap and provide estimates of root zone soil moisture that are informed by and consistent with SMAP observations. Such estimates are obtained by merging SMAP observations with estimates from a land surface model in a soil moisture data assimilation system.

Figure 1 shows the flow of the L4\_SM soil moisture analysis, which merges land model forecast soil moisture and soil temperature (FCST; at 9 km resolution) with horizontally and vertically polarized L-band brightness temperature observations (TBH, TBV; at 9 km and 36 km resolution, see below). The land surface model component of the assimilation system, the NASA Catchment land surface model [3], is driven with observations-based surface meteorological forcing data, including precipitation [4], which is the most important driver for soil moisture. The model also encapsulates knowledge of key land surface processes, including the vertical transfer of soil moisture between the surface and root zone reservoirs.

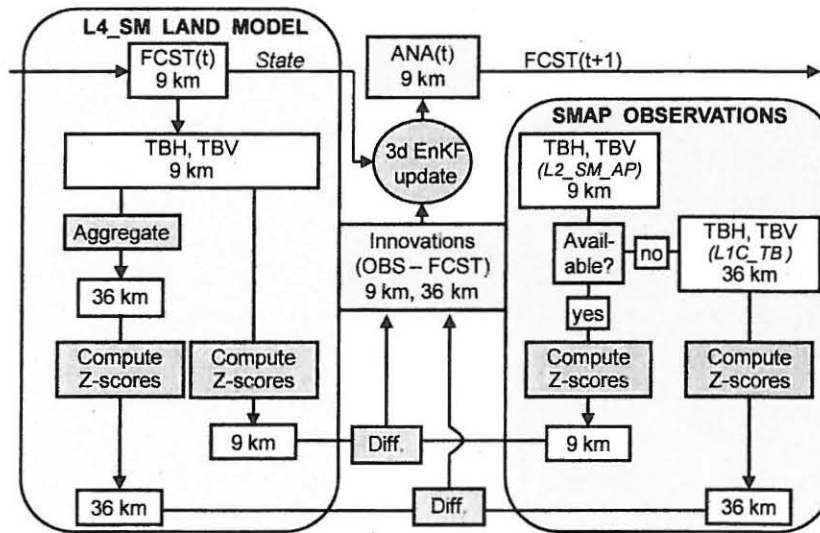


Fig. 1. The SMAP L4\_SM soil moisture analysis at time  $t$  merges land model forecast soil moisture (FCST) with horizontally and vertically polarized L-band brightness temperature observations (TBH, TBV) to compute a soil moisture analysis (ANA). In the prototype L4\_SM system SMOS observations at approximately 36 km resolution are used. The use of Z-scores (standard-normal deviates) addresses residual biases between modeled and observed brightness temperatures.

For the SMAP L4\_SM data product (Figure 1), downscaled TBH and TBV observations at 9 km resolution from the SMAP Level 2 Soil Moisture Active Passive (L2\_SM\_AP) product will be used whenever available. These downscaled brightness temperatures are a merger of the 36 km SMAP Level 1C Brightness Temperature (L1C\_TB) product and SMAP high-resolution radar observations, which are only available for the morning overpasses. For evening overpasses, the SMAP L4\_SM product will assimilate SMAP L1C\_TB brightness temperatures (at 36 km resolution). In the *prototype* L4\_SM system discussed here, SMOS brightness temperature observations are regridded to the 36 km SMAP grid and assimilated.

Residual biases between modeled and observed brightness temperatures are addressed through the use of Z-scores (standard-normal deviates; Figure 1). The horizontally distributed ensemble Kalman filter ("3d EnKF") update step considers the respective uncertainties of the model estimates and the observations, resulting in a soil moisture and soil temperature analysis (ANA) at 9 km resolution that is superior to satellite or model estimates alone. Moreover, error estimates for the L4\_SM product are generated as a by-product of the data assimilation system. In addition to the soil moisture analysis, the L4\_SM product also includes a freeze-thaw analysis (not shown in Figure1). The L4\_SM product thus provides a comprehensive and consistent picture of land surface hydrological conditions based on satellite observations and complementary information from a variety of sources.

The present paper will focus on the use of SMOS brightness temperature observations for the generation of a prototype SMAP L4\_SM product. The quality of the prototype product is assessed against in situ observations from operational watershed sites and sparse networks, including USDA/SCAN stations and stations in the Murrumbidgee basin in Australia. The assessment of the prototype product provides important information on the accuracy of the SMAP L4\_SM product relative to its RMSE requirement of  $0.04 \text{ m}^3 \text{m}^{-3}$ .

#### 4. CONCLUSIONS

SMAP will directly observe only surface soil moisture (in the top 5 cm of the soil column). The SMAP L4\_SM product is designed to provide estimates of root zone soil moisture (~top 1 m of the soil column) that are informed by and consistent with SMAP observations. Such estimates are important for several applications targeted by SMAP. The L4\_SM product is generated by merging SMAP observations with estimates from a land surface model in a soil moisture data assimilation system. Passive microwave observations from SMOS are available now and are used here for the generation of prototype root-zone soil moisture product, which is a critical step in the development of the SMAP L4\_SM data product.

## 5. REFERENCES

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